

**USAARL REPORT NO. 83-11**



**ATTENUATION VARIATION OBTAINED WITH SUBJECT FIT  
OF THE SIGMA ENGINEERING TRIPLE-FLANGE  
INSERT HEARING PROTECTIVE DEVICE**

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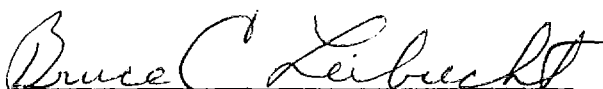
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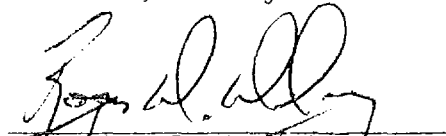


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The sound attenuation provided by a preformed triple-flange insert hearing protective device was determined when the user had no fitting instructions or training in the use of the device. This situation does occur in many instances among US Army personnel. The results of this study indicate that lack of training in the use of the Sigma Engineering Triple-Flange earplug reduces the available sound attenuation provided by the earplug by approximately 5 dB at most frequencies. Furthermore, the attenuation was more variable than that found in the "experimenter fit" group of subjects tested. Adequate fitting instructions should be developed and issued with the hearing protectors. Users should be trained in the use of the device.

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## INTRODUCTION

Laboratory procedures designed to evaluate the real-ear sound attenuation provided by a hearing protective device are defined in American National Standards Institute (ANSI) standard S3.19-1974 and its predecessor, USA standard Z24.22-1957. Within the ANSI S3.19-1974 standard are two methods of fitting an in-the-ear hearing protective device; one is "subject fit" and the other is "experimenter fit." The exact procedures are outlined in paragraph 3.3.3.1 of the 1974 ANSI standard. A significant difference in mean real-ear attenuation scores is obtained depending on the method used. This difference in attenuation scores indicates a potential minimal value the "average soldier" might receive without fitting and training in the use of the hearing protective device.

Padilla (1976) developed a field method of measuring earplug attenuation under a circumaural earmuff and found that experienced users of in-the-ear hearing protective devices obtained less attenuation than the manufacturer's specifications indicated. Regan (1977) and Edwards *et al.* (1978), found similar results in separate studies with a variety of in-the-ear hearing protective devices. They observed poorer attenuation than the manufacturer had indicated. Edwards noted that workers often wore the wrong size earplugs or inserted the earplugs improperly. Goldstein and Murphy (1980) found that training in the use of an insert hearing protective device increased the mean real-ear attenuation and reduced subject variability.

Every soldier has access to earplugs, but he may not have access to supervised fitting and instructions in the use of the earplug. The Sigma Engineering\* triple-flange insert earplug comes in three sizes. Each size is packaged separately with no fitting instructions in the package. According to field evaluation of hearing conservation programs performed by this author, the following methods of dispensing have been observed: (1) Insert hearing protectors are purchased based on minimal cost with no regard to size or the needs of the user. (2) Insert hearing protectors are provided to the user from unit supply where the user selects one pair. (3) Medical personnel might not perform the fitting of insert hearing protectors. (4) Fitting instructions, even in the form of posters, may not be available to aid in the proper insertion of the insert hearing protector. Therefore, it is important to know what amount of attenuation is obtained for the untrained person or "average soldier" with the preformed triple-flange insert earplug compared to the "experimenter fit" obtained in a laboratory environment.

The specific experimental questions are: (1) Does the untrained subject obtain comparable attenuation values to that of the "experimenter fit" subject without access to fitting instructions? (2) What size earplug does the untrained subject select compared to the required size?

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\*See Appendix A.

## METHOD

Twenty subjects participated in this study with 10 being naive subjects, having no prior experience with the preformed Sigma Engineering triple-flange insert earplug. All 20 subjects received a hearing threshold evaluation to determine if he/she met the ANSI standard S3.19-1974, paragraph 3.2.1 and 3.2.2 requirements. Each subject was trained and exposed to the measurement condition to insure familiarity with the test procedures. Each subject experienced the test procedure with and without attenuation using commercially available earmuffs. The training session was approximately two hours in duration and the subjects were given guidance and reinforcement to perform a threshold tracking task. The test conditions using the Sigma Engineering triple-flange earplug were conducted during the second session.

Group I subjects were fitted using the "experimenter fit" procedure as described in ANSI S3.19-1974 and tested in accordance with USA standard Z24.22-1957.

Group II subjects were provided with three boxes of Sigma Engineering triple-flange earplugs marked with the size. They were asked to select a pair of earplugs and to insert them. No fitting instructions were available to the subjects. Upon insertion, each subject then was taken into the soundroom and real-ear attenuation testing was conducted in accordance with USA standard Z24.22-1957.

The real-ear attenuation was determined by taking the difference between the threshold values obtained with and without the hearing protector. A free-field attenuated threshold was obtained with the subject facing a loudspeaker with his head fixed on a rest which maintained a constant head position. Next, a threshold measurement was taken under identical conditions with the earplugs fitted to the subject. This set of measurements was repeated three times. The mean of the three difference scores defined the real-ear attenuation.

## MATERIALS

In accordance with the USA standard Z24.22-1957, there was no audible ambient noise during the period of measurement. Camp (1969) presents noise levels and sound pressure level gradients of the Industrial Acoustics Company\* Model 1285-A audiometric room.

The test equipment consisted of the instrumentation shown in Figure 1. The tones were generated by a Fluke\* Synthesized Signal Generator 6010A. The output of the generator was connected to the input of a Grason-Stadler\* 1287-B electronic switch. The test tones were interrupted with a 50 percent duty cycle and with off and on durations of approximately 370 milliseconds,



which simulates the interruption rate of a clinical audiometer. The rise and decay times of the switch were 40 milliseconds each. The output of the electronic switch was connected to the input of a Grason-Stadler Model 1288 power amplifier. The power amplifier output was connected to a Grason-Stadler 1293 (10 ohm) step attenuator which was fed into a Grason-Stadler E-3262A recording attenuator.

The Grason-Stadler 1293 step attenuator provided the experimenter with a calibrated control of test tone levels for checking the subject's reliability. Also, it was used to control the sound pressure levels of the stimuli for subjects with extremely low thresholds. The Grason-Stadler E-3262A recording attenuator controlled the output level of the Altec\* 605B 15-inch loudspeaker and recorded the subject's response. The recording attenuator was controlled by the subject's photoelectric clickless switch which varied the attenuation as in a Békésy type presentation and could also be operated by the experimenter. The experimenter's switch had facilities for changing direction, stopping the attenuator, and overriding the subject's control.

The loudspeaker could deliver a sound field at the test frequencies such that the sound pressure level at the listener's position could vary from a maximum of 85 decibels (dB) above 20 micro pascals ( $\mu$ Pa) to a level below audibility. The voltage input to the speaker was calibrated at the beginning of each test with a Hewlett-Packard\* 3400 RMS voltmeter.

The test frequencies were pure tones of the following frequencies: 75, 125, 250, 500, 1000, 2000, 3000, 4000, 6000 and 8000 Hertz (Hz).

## RESULTS

The mean attenuation values, standard deviations, and range of scores for Groups I and II are presented in Table 1. Figure 2 plots the mean data to show the difference between the mean scores. On the average, this mean difference was 5 dB or greater at all test frequencies except 2000 and 3000 Hertz. A closer look at the standard deviations of the two test groups indicates greater variability in Group II with the "subject fit" as well as a wider range of scores at each test frequency. Figures 3 and 4 are scattergrams of the two groups demonstrating the variability in response within Group II compared to Group I.

Table 2 represents the observations noted by the tester relative to the subject's fit and the size selected by each subject. In three instances it was observed that a complete insertion of the plug was not achieved because the subject selected a size which was too large to provide a proper insertion. Furthermore, the subjects selected one size only and did not attempt to try any other size during the initial fitting period. In collecting Group I "experimenter fit" data, the tester noted some fitting variation in subjects from trial to trial. That is, the hearing protective device demonstrated some variability in fit even under ideal conditions.

# REAL EAR ATTENUATION TEST SYSTEM

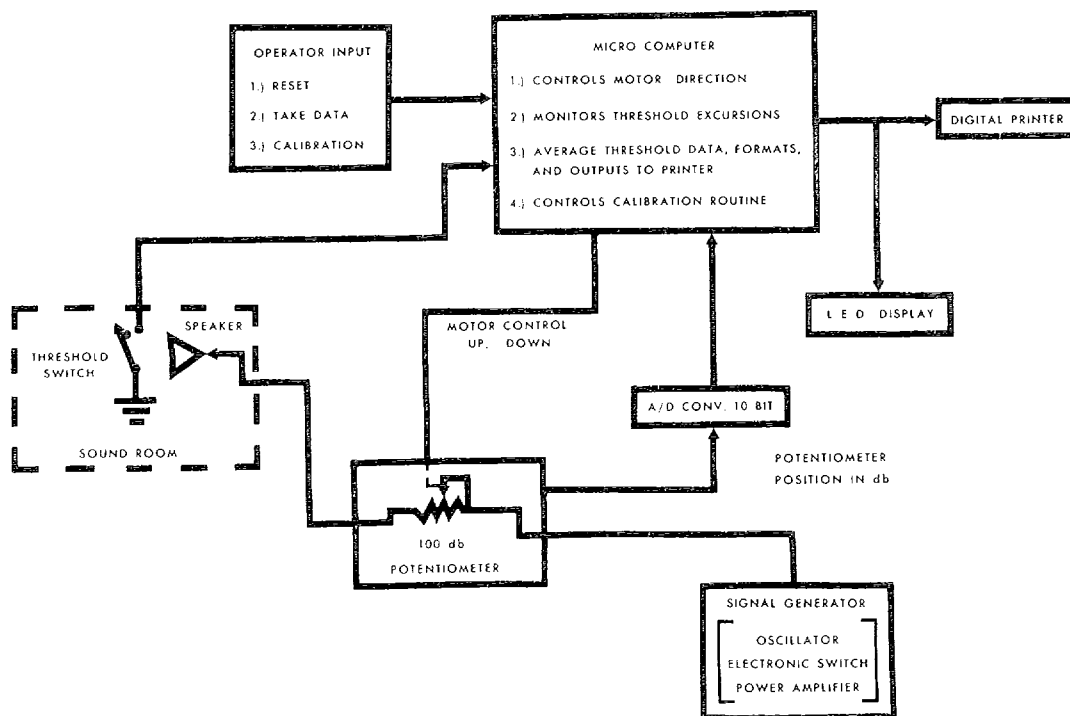


FIGURE 1.

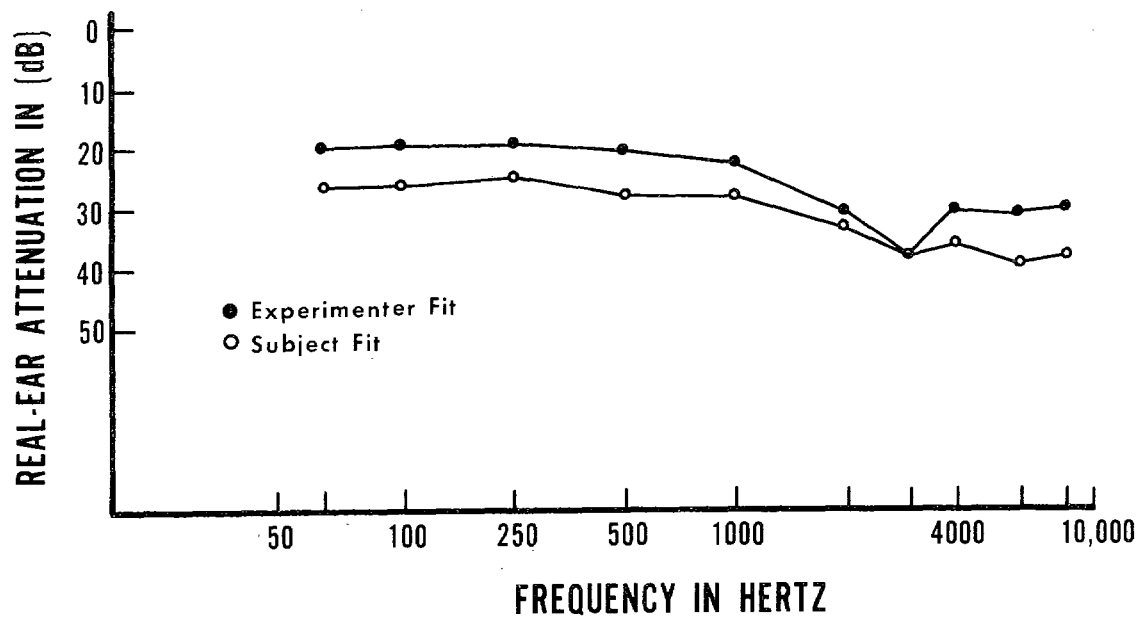


FIGURE 2. Mean real-ear attenuation characteristics of Groups I and II.

TABLE I  
MEAN, STANDARD DEVIATION AND RANGE OF SCORES  
FOR GROUP I "EXPERIMENTER FIT" AND GROUP II "SUBJECT FIT"

		<u>Test Frequencies in Hertz</u>									
		75	125	250	500	1K	2K	3K	4K	6K	8K
∞	Group I Mean	25.7	25.3	24.1	27.4	27.6	32.3	37.4	34.9	38.9	37.5
	S.D.	9.6	9.3	8.9	8.9	8.8	5.9	8.1	9.7	8.7	7.2
	Range	37.8	34.9	36.2	42.2	41.8	24.6	32.5	36.2	32.6	35.8
Group II Mean		19.93	18.99	18.59	20.54	22.38	30.29	33.4	29.24	30.28	29.19
S.D.		13.1	13.16	12.8	13.61	10.74	9.21	20.52	15.52	16.23	11.93
Range		46.0	45.2	47.3	43.6	33.2	33.6	38.2	37.0	59.2	40.0

Each group consisted of 10 subjects tested three times each for a total of 30 tests.

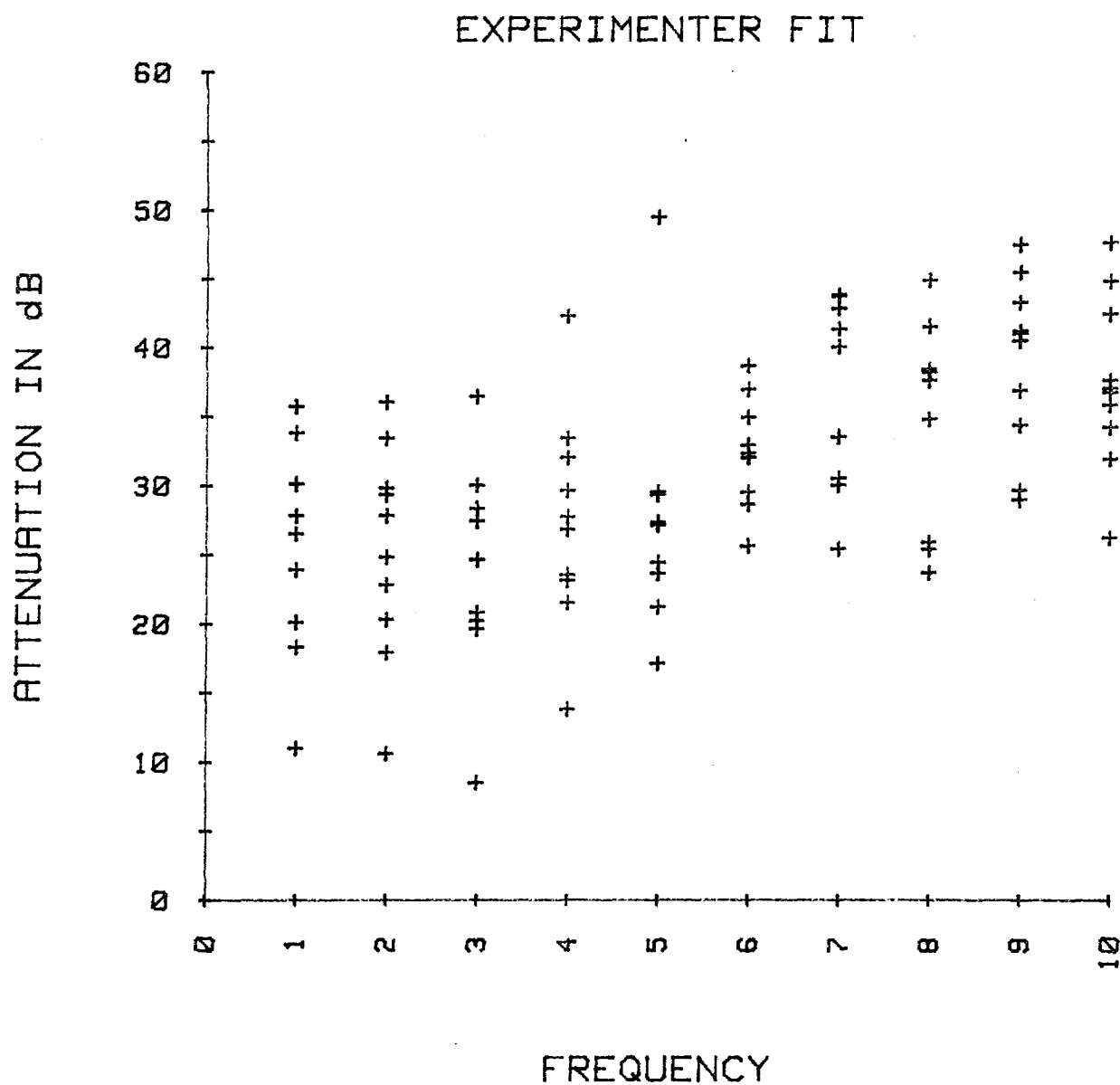


FIGURE 3. Scattergram of mean attenuation scores of the three responses of 10 subjects in the "experimenter fit" Group I for the 10 test frequencies of 75 Hz - 8000 Hz.

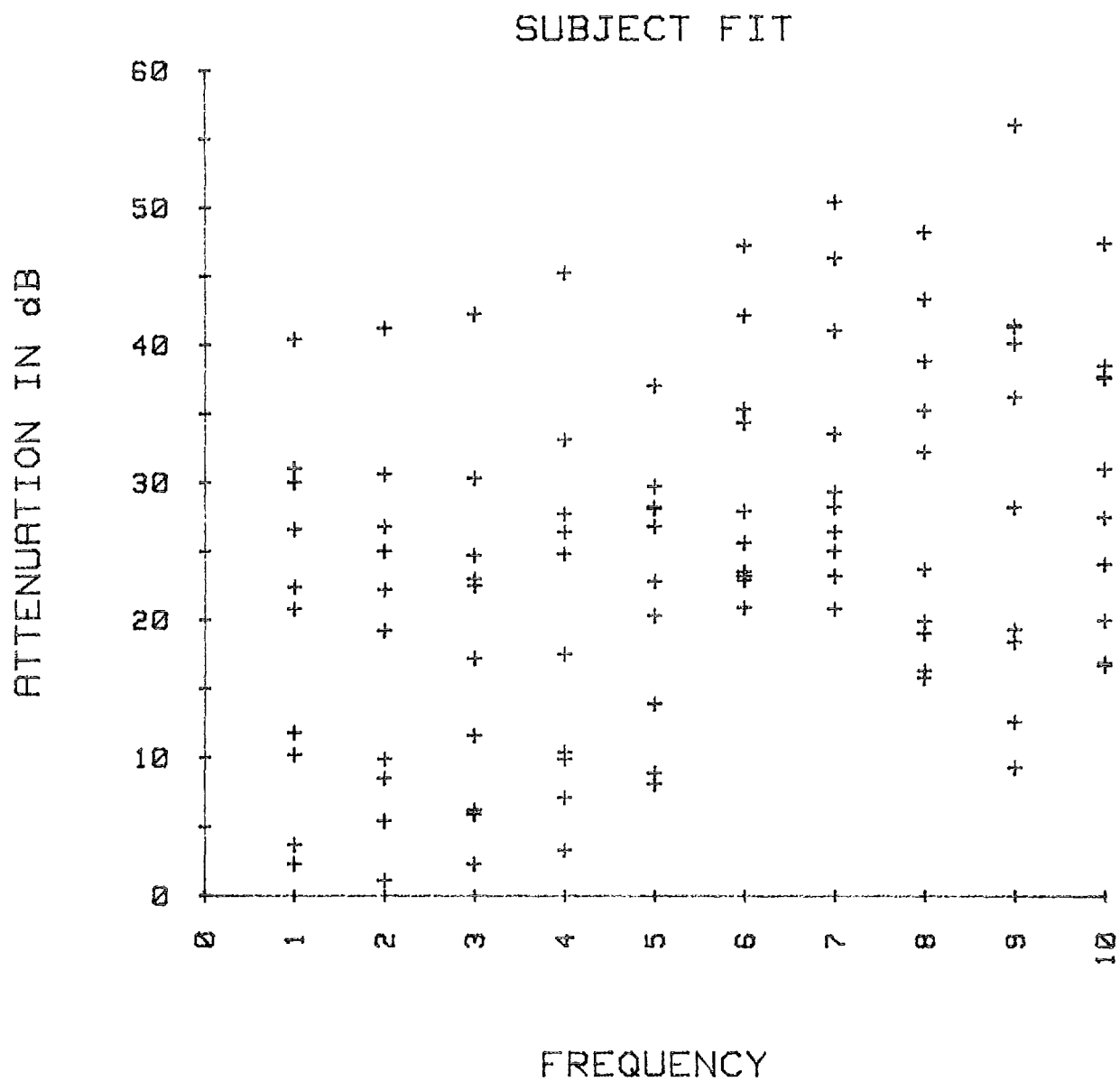


FIGURE 4. Scattergram of mean attenuation scores of the three responses of 10 subjects in the "subject fit" Group II for the 10 test frequencies of 75 Hz - 8000 Hz.

TABLE 2  
SUBJECT FITTING OBSERVED IN GROUP II

<u>Subject</u>	<u>Sex</u>	<u>Size plug</u>	<u>Fit</u>
1	F	S	Not in far enough
2	F	M	Not in far enough
3	F	M	Not in far enough
4	F	M	Fit okay
5	M	M	Fit okay
6	M	M	Fit okay
7	M	M	Fit okay
8	F	M	Fit okay
9	F	S	Fit okay
10	F	S	Fit okay

## DISCUSSION

Real-ear attenuation is considered the mean attenuation value of 10 individuals tested three times each by a standard method (USA Z24.22-1957). Therefore, the individual differences which occur in each trial are averaged. Specifically, variation in the hearing thresholds as great as 6 dB are acceptable within the three tests. An individual variation of either the subject or experimenter in fitting the device is introduced during each seating of the in-the-ear hearing protector device. The standard deviations and range of scores in Table I show this variation as well as Figures 3 and 4.

Group II's lower attenuation scores, larger standard deviations, and large range of scores indicates that the Sigma Engineering triple-flange hearing protective device will provide less attenuation with untrained users.

Training, according to Goldstein and Murphy (1980), was found to decrease the individual's variation in real-ear attenuation and improve the overall mean attenuation when compared with untrained subjects. It is felt that similar training in the use of this hearing protective device would also increase the mean real-ear attenuation to resemble the scores obtained under the "experimenter fit" conditions. Also, the findings of this study support earlier research which shows that "experimenter fit" real-ear attenuation scores overestimate the actual real-ear attenuation obtained by untrained subjects.

The majority of the 10 subjects in Group II selected a size of the Sigma Engineering triple-flange earplug which visually looked to be an appropriate fit. Furthermore, the size selection by sex of the subjects seemed appropriate in that the female subjects selected small or medium sizes and male subjects all selected medium-sized earplugs. This visual "good fit" may lead to a potential problem; that is, a fitted earplug that looks like a "good fit" may not be providing the maximum attenuation. Therefore, a visual inspection of fit may give some indication about potential attenuation but should not be considered the only indication of quality of fit, particularly with the Sigma Engineering earplug.

## CONCLUSION

The findings of this study indicate that the attenuation characteristics provided by the laboratory controlled "experimenter fit" are the ideal amount of attenuation one might expect from a hearing protective device, and real-ear attenuation obtained by the untrained user is significantly less than that found with the "experimenter fit." Furthermore, visual inspection of the proper fit of an insert earplug does not appear by itself to be the best indication of whether or not the maximum attenuation is being obtained.



## RECOMMENDATIONS

A copy of fitting instructions should be developed for insertion into the plastic carrying case, NSN6515-00-137-6345, for the triple-flange hearing protective device, NSN6515-00-442-4821, NSN6515-00-442-4818, and NSN6515-00-467-0092.

Stronger emphasis should be placed on supervisors to ensure that the users of the triple-flange hearing protector both read and understand the fitting instructions. The use of US Army Environment Hygiene posters and additional instructions available to the user are imperative to insure maximum hearing protection. Since this earplug is ordered in bulk and not individually packaged, such as the E-A-R\* earplug, NSN6516-00-137-6345, adequate instructions should be developed to be a part of the bulk package.

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## APPENDIX A

### LIST OF EQUIPMENT MANUFACTURERS

Sigma Engineering  
Safety Products Division  
Norton Company  
11320 Burbank Boulevard  
Hollywood, CA 91601

Industrial Acoustics Company, Inc.  
380 Southern Boulevard  
Bronx, New York 10454

John Fluke Manufacturing Company, Inc.  
P.O. Box 43210  
Mountlake Terrace, Washington 98043

Grason-Stadler, Inc.  
537 Great Road  
P.O. Box 5  
Littleton, MA 01460

Altec Lansing Corporation  
1515 S. Manchester Avenue  
Anaheim, California 93803

Hewlett-Packard Company  
P.O. Box 105005  
2000 South Park Place  
Atlanta, Georgia 30339

E-A-R Corporation  
7911 Zionsville Road  
Indianapolis, Indiana 46268